

## REMARKS/ARGUMENTS

The following remarks are made in response to the final action mailed August 11, 2009, and two declarations are submitted herewith, one by the co-inventor, Dr. Jean-Luc Meunier and the other by Dr. Maher Boulos, along with an RCE whereby consideration of this application is respectfully requested. The qualifications of Dr. Meunier and Dr. Boulos are set out in their respective CVs which indicate the scope and depth of their respective experience in the field of this invention.

A Supplementary IDS is enclosed which lists and includes all references cited in this response and the Declaration of Dr. Meunier.

### Status of Claims

Applicant notes that the Examiner did enter the amendment of July 27, 2009. Thus, at that time claims 1-3, 6-14 and 19-22 remained pending in the application. Claims 20-22 were new.

Applicant notes that the Examiner withdrew the previous 35 U.S.C.102(b) rejection of claims 1-3 as being anticipated by Smiljanic et al. (Chem. Phys. Lett., 356, 2002, 189-193). The basis for this was that the reference does not disclose a DC thermal plasma torch. In addition, the Examiner withdrew all previous 35 U.S.C. 103(a) rejections of claims 6-14 and 19 because of their dependence on claim 1. In this case, the primary reference relied on was the Smiljanic et al. reference noted above.

With this amendment, Claims 1, 3, 6, 8 to 14, and 22 to 25 remain in the application. Claims 1, 3, 6, and 8 to 14, and 22 have been amended. Claims 23 to 25 are new claims. Claims 2, 7, 19, 20, and 21 have been cancelled and original claim 10 remains.

An amended paragraph [0005] of the description has been submitted which provides amended statements of invention in respect of amended claim 1 and new claims 24 and 25.

### **Support for the Claims**

The claims as amended are supported throughout the description and the original claims. More particularly, reference may be had to paragraphs [0006], [0007], [0008] [0009], [0011], [0026], [0027], [0028], [0029], [0031], [0035], [0036] and [0041] of the published US application wherein support for the amended and new claim language can be found.

The Examiner will note the inclusion in new claim 25, of paragraph (d) having the following wording

“Using the cooling of the plasma stream above 107 ° C/s produced by the carbon-containing substance and carrier gas feed and by a supersonic shock created at the exit of the nozzle or the provision of an expansion in the nozzle internal diameter, generate *in-situ* nanometer sized tungsten catalyst particles ...”

Support for this language is found in the prior art, in particular reference may be had to the text Plasma Technology in Metallurgical Processing, Feinman, J. Ed., 1987 ( A Publication of the Iron and Steel Society, Inc.), See Page 57, where Fig. 5-23 illustrates “Temperature and axial velocity isocontours (after Vardelle et al<sup>20</sup>). A copy of each reference is attached. Calculations by co-inventor Meunier are found in his Declaration and confirmed by Boulos, which refer to the plasma stream temperature and which are based on the operating parameters specified in claim 25. No new matter is included here, given that this information represents the common general knowledge in the art of the priority date for the present application, namely November 15, 2002.

### **Claim Rejections – 35 USC S 112**

The Examiner has rejected claim 1 as being indefinite. More particularly, the Examiner rejected the claim for the use of the term “fast”, on the basis that it is a relative term and a rate would overcome the indefiniteness rejection. In response, Applicants have amended claim 1 so that the sequence of steps in the claim process are set out in a manner that illustrates exactly how they occurred. Further, rather than referring to

“fast quenching”, Applicants have chosen to define “a quenching zone downstream of the plasma torch for the formation of carbon nanostructures”. The selection of the catalyst metal determines the process parameters that will generate the desired catalyst metal vapour, which upon exposure to temperature conditions in the quenching zone will produce the metal catalyst nanoparticles that will act as catalyst nucleation sites for growth of the carbon nanostructures. The conditions do provide the necessary quenching to ensure that the catalyst metal nanoparticles are created in the quenching zone. The Examiner will note that in the Meunier declaration, calculations are done which attest to the temperatures being achieved in the plasma torch, and clearly because the quenching zone involves the introduction of a carbon gas substance feed together with a carrier gas, as well as a cooled nozzle and cooled reactor, the necessary quenching is achieved. The Examiner will note that similar language is used in new claims 24 and 25.

The Examiner has rejected claim 20 for lack of support in the application. Applicant has cancelled claim 20 for the Application and thus the Examiner’s rejection is moot.

### **New Art Rejection**

#### **Claim Rejections – 35 USC S 103**

**The Examiner has rejected former claims 1-3, 607, 11-12 and 22 under 35 U.S.C. 103(a) as being unpatentable over Smiljanic et al. (Chem. Phys. Lett., 356, 2002, 189-193) in view of Tsantrizos et al. (5,395,496), hereafter Tsantrizos #1 and Matsumoto et al. (JP 07061803).**

In order to establish a case of obviousness “the scope and content of the prior art are to be determined; differences between the prior art and the claims at issue are to be determined; and the level of ordinary skill in the art resolved. Against this background the obviousness or non-obviousness of the subject matter is determined. [Such secondary factors as commercial success, long felt but unrecognized needs, failures of others, etc., might be utilized to give light to the circumstances surrounding the origin of the subject matter sought to be patented.”] *KSR Int’l Co. v. Teleflex Inc.*, 127 S.Ct. 1727

(2007), citing *Graham v. John Deere Co.*, 383 U.S. 1 (1966).

In order to reject a claim based on a combination of references, as explained at **MPEP 2143** (citing the *Supreme Court in KSR v. Teleflex*), "Office personnel must resolve the *Graham* factual inquiries...

Then, Office personnel must articulate the following:

(1) a finding that the prior art included each element claimed, although not necessarily in a single prior art reference, with the only difference between the claimed invention and the prior art being the lack of actual combination of the elements in a single prior art reference;

(2) a finding that one of ordinary skill in the art could have combined the elements as claimed by known methods, and that in combination, each element merely performs the same function as it does separately;

(3) a finding that one of ordinary skill in the art would have recognized that the results of the combination were predictable; and

(4) whatever additional findings based on the *Graham* factual inquiries may be necessary, in view of the facts of the case under consideration, to explain a conclusion of obviousness.

*KSR*, 82 USPQ2d at 1395; *Sakraida v. AG Pro, Inc.*, 425 U.S. 273, 282, 189 USPQ 449, 453 (1976); *Anderson's-Black Rock, Inc. v. Pavement Salvage Co.*, 396 U.S. 57, 62-63, 163 USPQ 673, 675 (1969); *Great Atlantic & P. Tea Co. v. Supermarket Equipment Corp.*, 340 U.S. 147, 152, 87 USPQ 303, 306 (1950). "[I]t can be important to identify a reason that would have prompted a person of ordinary skill in the relevant field to combine the elements in the way the claimed new invention does." *KSR*, 82 USPQ2d at 1396.

### **The present invention**

There is provided a process for the manufacture of carbon nanostructures which may be carbon nanotubes or carbon nano-onions. The process involves the use of a high enthalpy metal electrode generated direct current thermal plasma torch which has a

plasma forming gas feed and is connected to a cooled reactor. A metal catalyst is selected, which then determines the parameters of the process. Torch power may range from about 30kW up to a multi-megawatt level and the flow rate of the plasma gas feed and the reactor pressure are selected to provide a torch temperature required to vaporize and maintain the selected metal catalyst in the vapor state. A feed of a carbon containing substance and a carrier gas at a selected flow rate is provided to the cooled reactor in a quenching zone downstream of the plasma torch for the formation of carbon nanostructures. When the metal catalyst vapor is contacted by the carbon containing substance and carrier gas feed, in situ generation of metal catalyst nanoparticles having a diameter of from about 2 to about 30 nm occurs, along with the formation of atomic carbon. The metal nanoparticles act as a catalyst and nucleation points for the growth of carbon nanostructures of about the same diameter range. The carbon nanostructures are then collected from the reactor.

The selection of the metal catalyst will determine the operating parameters required for the process. Inherently, the feed of carbon containing substance and carrier gas which is fed to the cooled reactor downstream of the plasma torch into the quenching zone of carbon nanostructure formation is substantially cooler than the plasma torch stream. This allows formation of the required metal catalyst nanoparticles and the atomic carbon which form the carbon nanostructures. Keeping the catalyst vaporized until it is quenched to form the nanoparticles ultimately ensures the formation of the carbon nanostructures.

**Smiljanic et al.**

The Meunier Declaration, confirmed by the Boulos Declaration indicates that Smiljanic discloses the fabrication of single wall carbon nanotubes using a microwave plasma reactor, a system operating in the non-thermal plasma regime meaning having different temperatures for electrons (light species) and atoms/molecules (heavy species), coupled to a furnace maintained at 1300° K, and having the carbon (ethylene) and catalyst (vaporized ferrocene) precursors injected in a vapor form into the microwave plasma. The calculations set out above clearly indicate that the process conditions now specified in the claims will produce temperatures that are not achievable

in a microwave plasma torch.

The claimed process involves vaporizing the metal catalyst and exposing the metal vapor to the quenching zone where the nano particles of metal catalyst are produced. There is no provision in Smiljanic to provide a quenching zone downstream of the torch, where quenching can occur through a variety of ways, such as a feed of carbon-containing substance and carrier gas, a cooled nozzle, which may have expanded nozzle geometry, supersonic shocks, and a cooled reactor.

### **Tsantrizos #1**

This reference according to the two referenced Declarations discloses the use of a DC thermal plasma torch for a homogeneous chemical reaction process to form fullerene molecules (C60 and C70) in a plasma environment specifically attempting to maintain a large and uniform temperature environment. Thus a combination of Tsantrizos #1 and Smiljanic does not provide the presently claimed process, since the vaporization of the catalyst metal to provide metal catalyst nanoparticles which act as nucleation points and catalyst for the growth of carbon nanostructures is not arrived at. There is no teaching of the handling of a metal vapor carrying thermal plasma stream for a heterogeneous reaction process based on the nanoparticles nucleated from the metal vapors.

Thus a combination of Tsantrizos #1 and Smiljanic does not provide the presently claimed process, since vaporization of the catalyst metal to provide metal catalyst nanoparticles which act as nucleation points and catalyst for the formation of carbon nanostructures in the presence of atomic carbon are not found in either reference.

**Smiljanic and Tsantrizo #1 motivated by Matsumoto**

In Matsumoto, according to the Meunier and Boulos Declarations there is disclosed the use of an inductively coupled plasma using carbon powders only, with no use of catalyst being specified, to form a very low yield (5-10%) of a mixture of fullerenes and carbon nanotubes. Matsumoto does not teach a heterogeneous reaction involving the handling of metal vapors for the formation of nanoparticles of catalyst. This reference does not motivate the combination of Smiljanic and Tsantrizos #1 for these reasons. In this regard, reference should be had to the Meunier Declaration and the confirming Declaration of Boulos, in particular to paragraph 13. wherein it is stated

*“Even at the present time, other researchers and experts in the field of thermal plasmas are indicating their unsuccessful attempts to produce CNTs using the DC thermal plasma torch technology (this was officially indicated at the 2007 Round Table on Thermal Plasma Technology, Sharm El Sheik, Egypt; it also follows from the absence of thermal plasma torch papers on this topic (apart from those of Harbec and Meunier) in the International Symposium on Plasma Chemistry (most important international conference for thermal plasma technology) up to year 2007).”*

This clearly indicates that motivation to combine different technologies is truly tempered by a landscape of failures which certainly temper the potential combinations, including the one proposed here by the Examiner.

From the foregoing, Applicants respectfully submit that combining Smiljanic and Tsantrizos #1, with the teachings of Matsumoto in mind, does not lead to the presently claimed process which involves a quenching zone downstream of the torch and conditions leading to supersonic flows, such as stream expansion in the nozzle, pressures below atmospheric, and very high plasma flow rates, which are not taught or suggested in the combination of the three references. This is all supported by the Meunier and Boulos Declarations which clearly indicate that the art skilled person would not conclude as the Examiner has suggested in this rejection.

Clearly the Graham factual inquiries, namely determining the scope and content of the prior art; the differences between the prior art and the claims at issue; the level of

ordinary skill in the art, only reveal that a finding of obviousness cannot be supported by the cited references. The combination does not provide all of the elements of the claimed process, because the Graham factual inquiries cannot be resolved. Leaving this result aside, it is not possible to articulate the finding that the prior art includes each element claimed, and certainly not in a single prior art reference, with the only difference between the prior art and the claimed invention being the lack of the actual combination of all of the claim elements in a single prior art reference. Thus the analysis laid out under KSR, cannot be conducted and Applicants would respectfully submit that the Examiner's rejection under § 103 cannot be sustained.

In view of the above and foregoing, it is respectfully requested that the Examiner withdraw his rejection of claim 1, as well of claims dependent thereon, under 35 U.S.C. § 103.

**Claims 8-10 and 19 are rejected under 35 U.S.C. § 103(a) as being unpatentable over Smiljanic, Tsantrizos #1, and Matsumoto as applied to claims 1 and 7 above, and further in view of Tsantrizos et al. (5,147,998), (hereinafter Tsantrizos #2).**

In Applicants' opinion, this rejection also fails for the same reasons stated above. The selection of tungsten as the catalyst metal is not obvious given that the rejection is based on the first three references. The combination of references does not provide the claimed process with respect to amended Claim 8, and also amended Claim 1 and therefore the Graham factual inquiries cannot be resolved in a manner that allows the KSR deliberations to be made. Given that the first three references fail to disclose in combination the features of the process claimed in the rejected claims, the combination with Tsantrizos cannot succeed either, because it is not soundly based. It should be noted that Claims 7 and 19 have been cancelled.



**Rejection of claims 13-14 and 21 as being unpatentable in view of Smiljanic, Tsantrizos #1, and Matsumoto as applied to claim 1 and further in view of Cohen et al. (5,993,697).**

Cohen teaches the use of metal catalyst in the atomic scale (gaseous state) reacting with carbon atoms on graphene sheets in order to transform the sheets into pentagonal and heptagonal bonding structures. Cohen does not teach the use of metal nanoparticles to act as a catalytic template to form the tubular structure of carbon nanotubes. It is not obvious for a person of ordinary skill to transform the teaching of Cohen into a template driven process using a series of controlled sequential steps. Further the combination of references does not provide what is set out in the rejected claims and thus the obviousness rejection fails for not satisfying the Graham factual inquiries and thus for not permitting the KSR analysis. Claim 21 has been cancelled as noted earlier. This rejection, in Applicants' respectful view should be withdrawn.

**Claim 20 is rejected as being unpatentable in view of Smiljanic, Tsantrizos #1, Matsumoto, and Cohen as applied to claim 13 and further in view of Geobegan et al. (2002/0179564).**

This claim has been cancelled and therefore the rejection is moot.

### **Response to Argument**

As the Examiner will appreciate Applicant has amended the claims in view of the Final Action and would submit that all of the points noted by the Examiner in this section of the Action have been addressed earlier in this response.

### CONCLUSION

The rejections of the claims are believed to have been overcome by the present amendments and remarks. Favorable consideration in the form of a Notice of Allowance is believed to be next in order, and such an action is earnestly solicited. Should the Examiner have any questions or require further clarification, please contact the undersigned by telephone.

Respectfully submitted,

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